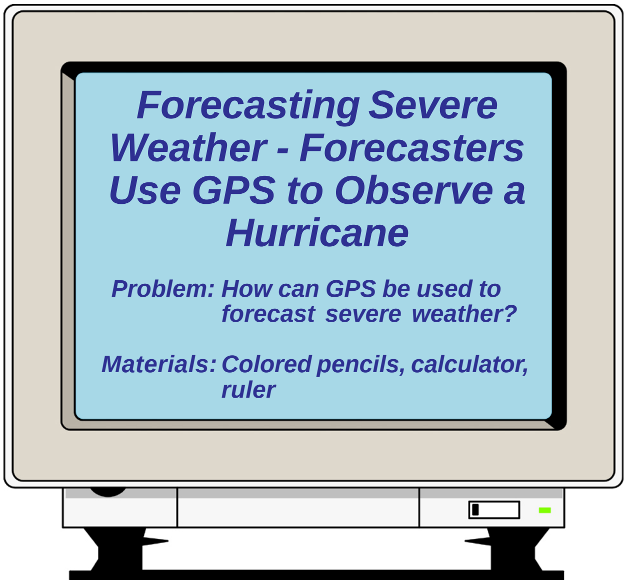

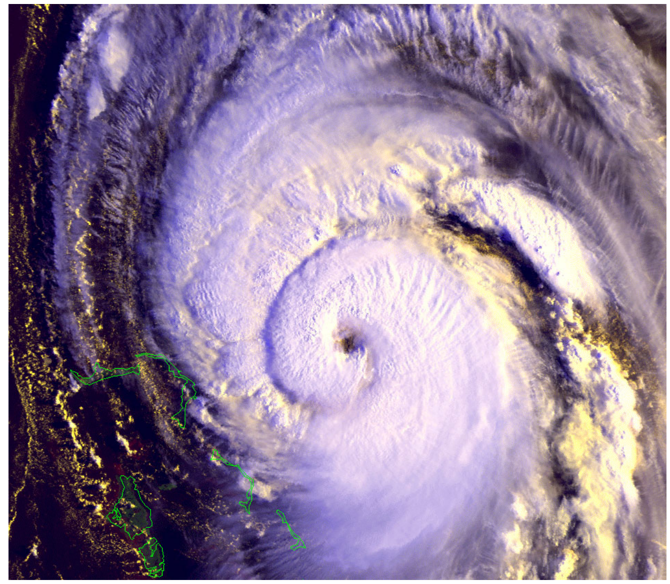

FYI

Global Positioning System (GPS)

GPS is a series of well-spaced satellites that orbit the Earth and make it possible for people who have ground receivers to pinpoint their geographic location (latitude and longitude). Owned and operated by the U.S. Department of Defense, twenty-four satellites provide accurate data that were not available before the early 1990's. Researchers use GPS data to measure movement of arctic ice sheets, the Earth's tectonic plates and volcanic activity, and more recently, for meteorology research.

Background

No electricity, houses toppled and collapsed, roads flooded and washed away. This time it was Hurricane Georges! Even though the hurricane was long gone, its effects lingered along the US Gulf Coast. Still worse, over 500 people died in the Caribbean, mostly from flooding and mudslides in rural, mountainous areas.

Meteorologists, researchers, and forecasters work to improve weather forecasts, especially forecasts of severe weather. The goal is to save lives, prevent property damage, and to allow life to go on as usual in spite of the weather. But people need time to prepare for these catastrophic events. One factor limiting timely forecasts is a lack of information about water vapor in the atmosphere. The amount of water vapor in the atmosphere varies greatly over short distances and short periods of time. For example, some people have experienced watching rain on one side of a street while standing in the sun on the other side of the street, or watching puffs of clouds drift by with lots of water but no precipitation. Most of us have experienced a brief rain shower, only to find the sun shining within a few minutes.

Water travels rapidly through the atmosphere. Billions of gallons of water exist in the atmosphere. Like fuel in an engine, water vapor provides energy in the form of convection. In convection, water evaporates (taking up heat), expands in the atmosphere, then cools, and condenses. When vapor condenses, it gives off heat. This heat is like high-octane fuel, providing the energy for thunderstorms, tornados, and hurricanes. During a hurricane, for example, water vapor comes from the warm ocean water below. Once the hurricane reaches land, its fuel supply disappears and the hurricane rapidly fades away. Not only does water vapor affect weather events, it also plays a critical role in the global climate system. For example, water vapor is a greenhouse gas, and it influences air pollution. Water vapor also refracts (slows-down and bends) radio waves, including GPS signals. When this happens, the apparent distance between a GPS satellite and a receiver on the ground is a little longer than it would be if the air were completely dry. This means that your GPS position may be a little less accurate when the sky is cloudy than when it is clear.

The slowing of the GPS signals created large errors when people tried to use GPS to make very accurate measurements over long distances. Scientists investigating the cause of these errors realized that the errors were mostly coming from local changes in atmospheric water vapor. They developed techniques to estimate and remove the errors so their measurements of things like continental plate motions could be made much more accurately. Little did they realize that they had invented a new weather observing system: GPS meteorology! This promising new ground-based meteorological observing system is inexpensive and effective. Here is how it is set up: NOAA uses already existing GPS sites to receive measurements for the total amount of water vapor above a GPS antenna. Scientists call this “precipitable” water vapor.

FYI

Precipitable Water Vapor

Imagine a cylinder where the base measures one meter and the sides reach to the top of the atmosphere. Precipitable water vapor is the amount of water that would form if the entire amount of vapor in the cylinder were condensed or precipitated.

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On the same sites they installed two surface meteorological sensors, a barometer and a thermometer. From this combined information, meteorologists expect to have significant improvements in short-term weather forecasts, especially severe weather forecasts.

The low cost GPS system improves the reliability for predicting precipitation amounts because of its high measurement accuracy and the ability to operate under a variety of conditions. It has the added benefit of operating long-term for climate monitoring. More importantly, the GPS system can accurately forecast heavy precipitation caused by severe weather. Therefore, forecasters come a bit closer to their goal of saving lives, preventing property damage, and allowing life to go on as usual in spite of the weather. They have a better ability to allow people needed time to prepare for destructive events.

Initial results from NOAA's demonstration GPS network have been encouraging. Despite high winds, heavy precipitation, and cloud cover, water vapor measurements were successfully measured for the first time as Hurricane Georges came ashore between Biloxi and Gulfport, Mississippi on September 28, 1998.

Procedure

In the procedure that follows, you will use the amount of precipitable water vapor measured in centimeters and surface air pressure measured in millibars to follow the development of Hurricanes Georges. The data included in this activity are actual data used by researchers at the National Oceanic and Atmospheric

FYI

Julian Calendar

The Julian Calendar was introduced in Rome in 46 B.C. It established the 12-month year of 365 days with each fourth year having 366 days. The months each had 31 or 30 days except for February, which had 28, or in leap years 29 days.

Gregorian Calendar

The Gregorian Calendar is in general use today. It was introduced in 1582 by Pope Gregory XIII as a revision of the Julian calendar. The Gregorian Calendar was adopted in Great Britain and the American colonies in 1752. It has leap years in every year divisible by four with the restriction that century years are leap years only when divisible by 400.

Administration (NOAA) Forecast Systems Laboratory, in Boulder, Colorado. Sometimes researchers find it convenient to use a calendar that simply counts days in numerical order beginning with the first day of a new year. The Julian Calendar version used in this activity begins with day 1 of 1998 and simply numbers each successive day - day 1, day 2, day 3, etc. Furthermore, each day used in these data is divided into decimal fractions.

1. Using Table 2.1, convert Julian Calendar dates to Gregorian Calendar dates by filling in the columns for your calculations and calculation-derived values for day and time, in hours and minutes, using the following directions.

a. Day 268 is September 25, 1998. Day 269 is September 26, etc. Fill in the month and day for each Julian Calendar day.

b. The decimal that follows each day gives the time for that day in decimals. To convert day 268 to hours and minutes requires two steps. Follow the directions provided in the bulleted steps that follow.

Note: To help you understand how to do the calculations, the results of the first two time computations are provided.

- To convert to hours, simply multiply 24 hours times the decimal part of the date (from Column 1 - Table 2.1). Round your result to the nearest one hundredth.

  Record your result in the "Hours Calculation" column of Table 2.1. The first two are already done for you. Check them to verify the procedure.

  Note: (If there is no whole number, then there is no hour in military time [00 - 23], only minutes. But in civilian time [1 - 12AM/1 - 12PM], if there is no whole number, the hour becomes 12 midnight [PM])

- To convert hours to minutes, simply multiply 60 minutes times the decimal part of the hour results. Round your result to the nearest whole number.

  Record your result in the "Minutes Calculation" column of Table 2.1. The first two are already done for you. Check them to verify the procedure.

c. Combine the "Hours" and "Minutes" columns to fill in the "Gregorian Calendar Time." Remember to label "AM" and "PM."

d. Fill-in the Gregorian days and times on the x-axis of Figure 2.1. The first day and first two times are already done for you.

2. Using Table 2.1, round off each precipitable water vapor reading to the nearest tenth. Record your results in the appropriate column of Table 2.1. Then, using Figure 2.1, plot the points corresponding to the precipitable water vapor for each time provided.

3. Using Table 2.1, round off surface air pressure to the nearest whole number. Record your results in the appropriate column of Table 2.1. Then, using Figure 2.1, plot the points corresponding to the surface air pressure for each time provided.

4. Write a title for your graph on the line provided in Figure 2.1.

Julian Calendar (Day &Time)	Gregorian Calendar (Day)	Hours Calculation	Minutes Calculation	Gregorian Calendar Time (Hrs. & Mins.) (00:00)	Precipitable Water Vapor (cm)	Precipitable Water Vapor (cm - rounded)	Surface Pressure (mb)	Surface Pressure (mb - rounded)
268.0104	9/25/98	0.25	15	12:15 AM	3.814	3.8	1015.230	1015
268.2604	9/25/98	6.25	15	06:15 AM	3.543	3.5	1015.380	1015
268.5104	9/25/98				4.035		1015.630	
268.7604	9/25/98				4.734		1015.400	
269.0104					4.325		1014.580	
269.2604					4.287		1014.230	
269.5104					4.400		1014.600	
269.7604					4.727		1013.880	
270.0104					5.984		1011.950	
270.2604					5.702		1008.800	
270.5104					5.960		1006.780	
270.7604					6.567		1003.200	
271.0104					7.026		994.580	
271.2604					7.226		987.900	
271.5104					7.009		991.100	
271.7604					6.790		995.030	
272.0104					6.600		995.650	
272.2604					6.658		994.675	
272.5104					6.477		997.650	
272.7604					6.268		999.450	
273.0104					4.984		1002.150	
273.2604					4.313		1003.575	
273.5104					3.958		1006.275	
273.7604					3.947		1007.475	

Table 2.1. Julian/Gregorian Day and Time, Precipitable Water Vapor, and Surface Pressure Data for Hurricane Georges

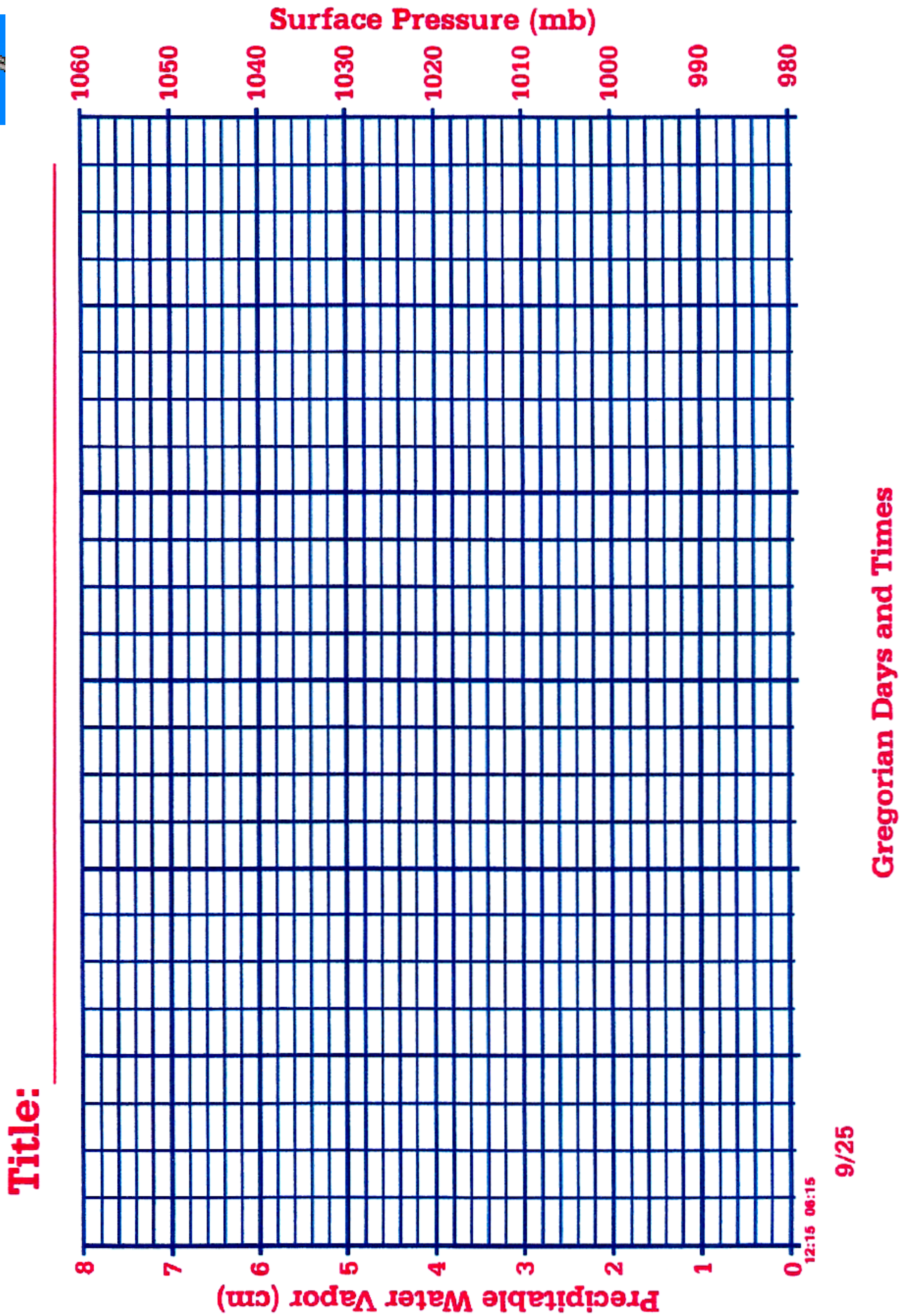

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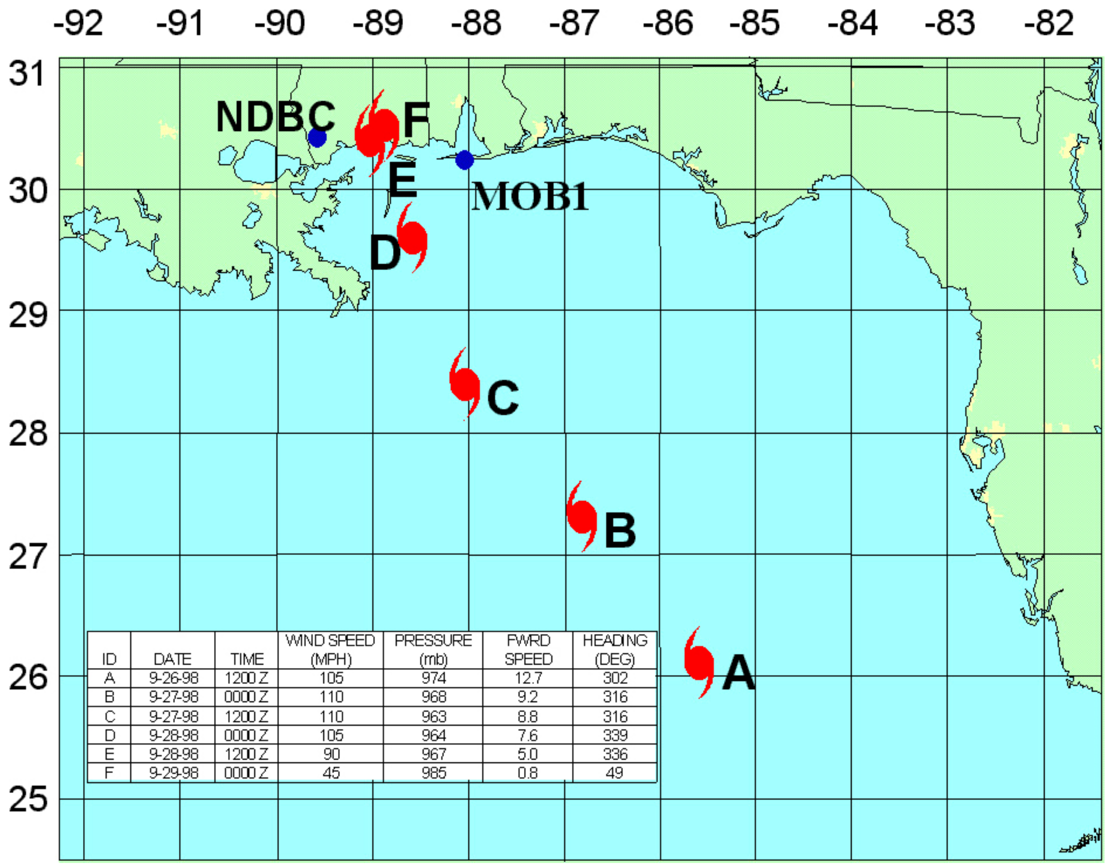
Figure 2.1. Precipitable Water Vapor and Surface Pressure vs. Gregorian Day/Time for Hurricane Georges



ID	DATE	TIME	WIND SPEED (MPH)	PRESSURE (mb)	FWRD SPEED	HEADING (DEG)
A	9-26-98	1200 Z	105	974	12.7	302
B	9-27-98	0000 Z	110	968	9.2	316
C	9-27-98	1200 Z	110	963	8.8	316
D	9-28-98	0000 Z	105	964	7.6	339
E	9-28-98	1200 Z	90	967	5.0	336
F	9-29-98	0000 Z	45	985	0.8	49

Figure 2.2. Track of Hurricane Georges - 9/25/98 to 9/29/98 - Letters Correspond to the Location of the Images in Figures 2.3A through 2.3F

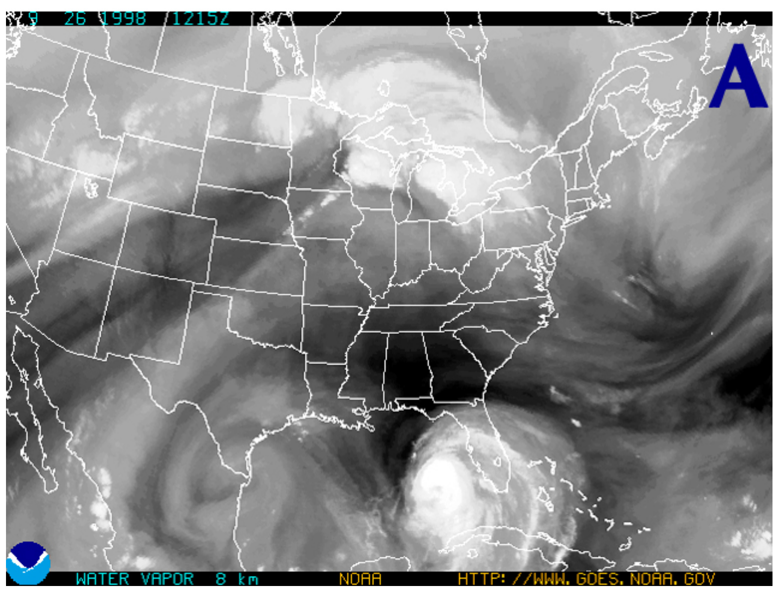
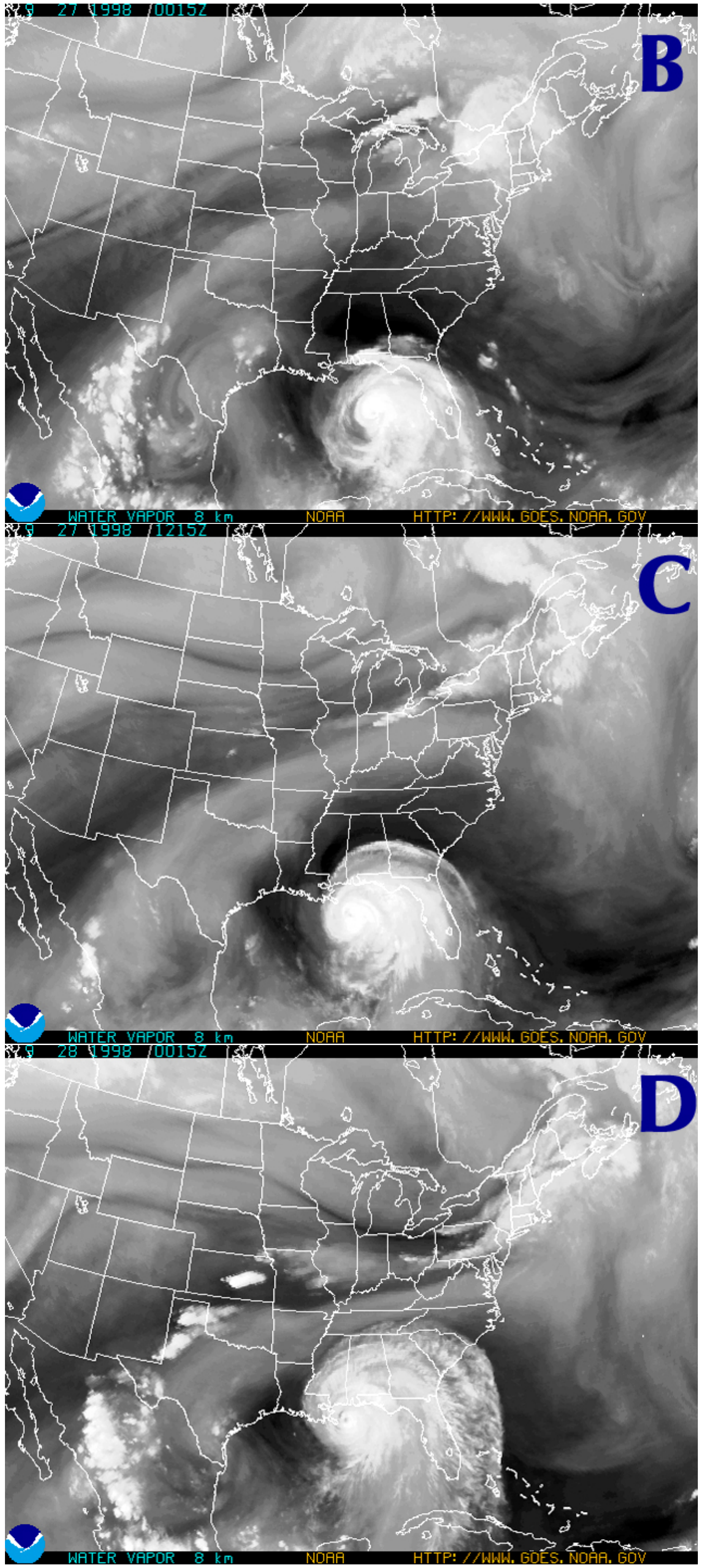
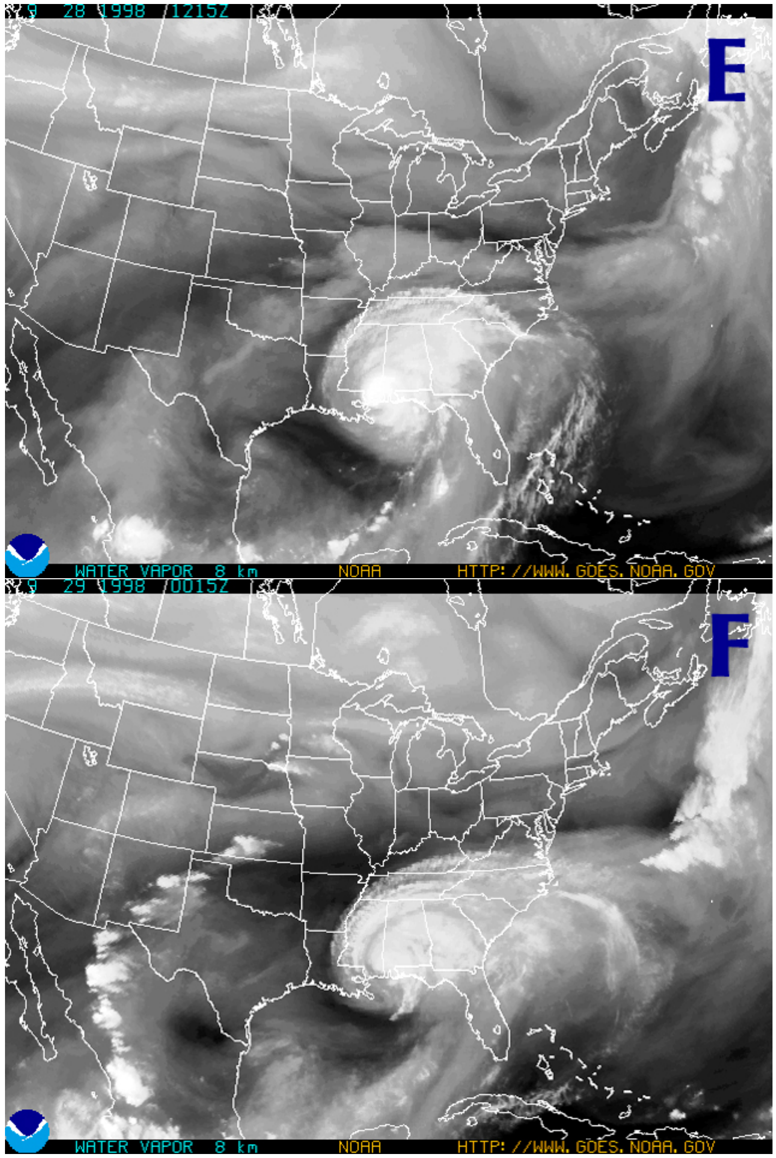


Figure 2.3A. GOES-8 Satellite Water Vapor Image of Hurricane Georges - Letter Corresponds to the Points on Figure 2.2



Figures 2.3B, C, and D. GOES-8 Satellite Water Vapor Image of Hurricane Georges - Letter Corresponds to the Points on Figure 2.2



Figures 2.3E and F. GOES-8 Satellite Water Vapor Image of Hurricane Georges - Letter Corresponds to the Points on Figure 2.2

FYI

Greenhouse Gases

Greenhouse gases cause heat that is radiated by the Earth's surface to be reflected back down toward Earth, causing the air to warm. Although the best known greenhouse gas is carbon dioxide, the most plentiful greenhouse gas is water vapor, a naturally occurring gas that is enhanced by human-added pollutants. The amount of water vapor that can be held in the air is strongly influenced by the temperature of the atmosphere. Under the right circumstances, water in the atmosphere may contribute to a runaway greenhouse effect through the formation of a positive feedback loop.

Questions

1. According to the Gregorian Calendar, on what day and at what time did the highest amount of precipitable water occur?

2. According to the Gregorian Calendar, on what day and at what time did the lowest surface air pressure occur?

3. What is the relationship between the amount of precipitable water and surface air pressure over time?

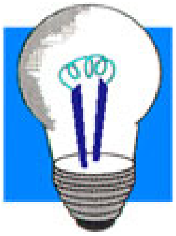
4. Why is information about the amount of water vapor in the atmosphere important to forecasters?

5. What are the advantages of the GPS system?

6. Using your graph for precipitable water vapor and Figure 2.3B of Hurricane Georges, explain why there is a slight jump (spike) in the amount of precipitable water vapor on the graph just before the peak for the amount of precipitable water vapor from the full force of the hurricane.

7. Why does the graph for precipitable water slope steeply on one side and not the other?

8. Using Figure 2.2, the diagram for the track of Hurricane Georges, explain the changes in wind speed.



Conclusion

Review the problem stated on the first page and write a detailed conclusion.